

TAMPERE UNIVERSITY OF TECHNOLOGY
*Master's Degree Programme
in Biomedical Engineering*

MUHAMMAD WASIM MUNIR
TRACKING DEVICES FOR ELDERLY CARE
SYSTEM BY USING GPS AND RF TAGS
Master of Science Thesis

Examiner: Professor Kari Mäkelä
Supervisor: Sami Perälä
Examiner and topic approved in
Biomedical Engineering
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ABSTRACT

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At present, elderly people are suffering from dementia and Alzheimer's disease across the world. The aged population has been increasing and will continue to do so in the coming decades. Those elderly who are suffering from dementia and Alzheimer's disease require continuous attention. So these people need a responsible person (either a nurse or family caretaker) to look after and provide support in any case of emergency. The number of these patients is dramatically increasing. This is difficult to care for them all by hiring a personal caretaker for each patient. Consequently, with the help of electronics and computer technology, scientists currently develop efficient and user-friendly devices that can help look after a patient easily or even remotely. Hence it is possible to look after not only a single patient but also monitor a number of patients at the same time. In this thesis, after a brief study about elderly tracking devices, the limitation was identified, and relevant improvements were suggested for the devices. A survey has been conducted to present the opinion of consumer of LDS Finder and Teltonika HandHeld tracking devices. A website was developed in which relevant information is available regarding the availability of the tracking devices for the elderly.

PREFACE

This document is the diploma work for the MSc. program of the Biomedical Engineering Department at the Tampere University of Technology. This work focuses on two relevant fields: Telemedicine and Healthcare with comprehensive research on tracking devices for elderly care especially those utilizing GPS (Global Positioning System) and RFID (Radio Frequency Identification) technologies. This work was done in collaboration with the Telemedicine Laboratory of Tampere University of Technology and the Etelä-Pohjanmaan Terveysteknologian Kehittämiskeskus ry (EPTEK) located in the MediWest Technology Center in Seinäjoki about 180 kilometers north of Tampere.

Professor Kari Mäkelä, thesis examiner, is head of the Telemedicine Laboratory at the Tampere University of Technology in Seinäjoki. Sami Perälä, research supervisor, is the Executive Director of the EPTEK Company.

I thank Allah who has aided me and given me strength to work hard on this research project and also for helping me develop a keen interest in this field. Moreover, I am thankful to Professor Dr. Kari Mäkelä who gave me the opportunity to work with him in the latest field of healthcare research. I am also grateful to Mr. Sami Perälä, who helped me in finding the different tracking devices manufactured in Finland and introduced me to his work in telemedicine and healthcare. I wish to express my gratitude to Juha Nousiainen for their support and guidance. Finally, I would like to thank my parents, siblings and friends whose appreciation and motivation was apparent throughout the duration of my work.

I hope this document is not difficult to understand even for those not acquainted with terminology found in the medical and telecommunication fields. I have done my best to make all the information clear and self-explanatory. If you have any further inquiries regarding my work, please do not hesitate to contact me.

Muhammad Wasim Munir

Email: muhammad.munir@tut.fi
wasimmunir@yahoo.com

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TERMS AND DEFINITIONS

2G	Second Generation: 2G is wireless telephone technology based on digital communication including GSM offer auxiliary services such as data and SMS (Short Message Service). 2G protocols support high bit rate voice and limited data communications that are widely using in all over the world.
2.5G	Second and Half Generation: 2.5G is an intermediate standard between 2G and 3G wireless technologies. 2.5G protocols extend 2G technology to provide additional features such as packet-switched connection (GPRS) and enhanced data rates (EDGE, HSCSD).
3G	Third Generation: 3G is the third generation of wireless communication standards superseding 2.5G. 3G is operating at high-speed for multimedia data and voice.
4G	Fourth Generation: 4G is emerging technology that integrates different modes of wireless communications and it is the name of technologies for high-speed wireless communications designed for fast data services and interactive TV through mobile network.
A-GSP	Assisted GPS: A-GPS enhances the startup performance of a GPS satellite-based positioning system.
ASP	Active Server Pages: ASP Classic is Microsoft's first server-side script engine for dynamically generated web.
BS	Base Station: The radio transmitter or receiver that communicates with mobile phones within a specific range.
BTS	Base Transceiver Station: A base transceiver station is equipment that facilitates wireless communication between mobile phone and network.
ERD	Entity Relationship Diagram: In software engineering, an ERD represents the various data tables and interfaces in a system, and there connectivity.
E-Health	e-Health is relatively recent term used for healthcare practice that provided by electronic processes and information technology.
FDA	Food and Drug Administration: A federal agency in the United States Department of Health and Human Services established to control the release of new foods and healthcare products.
GPRS	General Packet Radio Service: A packet oriented mobile data service extension to GSM networks that offers data transfer rates of up to 114 kbps.
GPS	Global Positioning System: A global navigation system that uses satellite technology and portable receiving units to determine latitude and longitude positioning on Earth accurately.
HL-7	Health Level 7: It is an organization that involved in development of international healthcare standards for the exchange, management and integration of electronic healthcare information.

IC	Integrated circuit: It is a small electronic circuit created in single piece of semiconductors like silicon.
IP	Internet Protocol: A unique numeric address assigned to a computer's network card that allow to access on Internet and network as unique identification.
ISDN	Integrated Service Digital Network: It is based on digital transmission that allows voice and data traffic to use the same digital links and exchanges.
IM	Instant Messaging: It is a form of real-time communication between two or more people based on typed text like messengers.
IP-67	International Protection Rating: This IP Code categorizes the degrees of protection provided against the intrusion of hard objects, accidental contact, dust, and water in electrical enclosures.
JSP	JAVA Server Pages: It is a Sun Java technology that permits software developers to create dynamically generated web sites, with HTML, PHP, XML, or other web developing tools.
MMS	Multimedia Messaging Service: It is a telecommunications standard for sending messages that include multimedia data (images, audio, video)
MSC	Mobile Switching Center: The central communications hub of a mobile phone system that is responsible for routing all the calls from the different base stations to other base stations.
P2P	Peer-to-Peer: It is a system in which two or more nodes or processes can initiate communications with each other.
PTT	Push to Talk: It is a two-way communication service that works like a walkie-talkie using a button switch.
OSI	Open Systems Interconnection: It is an abstract model comprising seven layers concerned with the communication of data between two peer systems or between a client and a server.
RFID	Radio Frequency Identification: The use of electromagnetic tags that can be stuck or embedded into a product to uniquely identify that object.
SMS	Short Messaging Service: It is a text messaging communication service standardized in the GSM mobile communication system.
TCP	Transmission Control Protocol: It is a protocol standard that used along with the Internet Protocol to send data in the form of packets between computers over the Internet.
Tele-Health	It is the delivery of healthcare services and information via telecommunications technologies.
UDP	User Datagram Protocol: It is an unverified transportation protocol that sends data from one program to another using Internet Protocol.
WAP	Wireless Application Protocol: It is a technology standard that providing mobile phones, pagers and other handheld devices with secures access to webpage and email.

CHAPTER 1

Introduction

- Healthcare
- Aims of Thesis

1.1. Healthcare

Elderly care is a branch of health care. The telecommunication technology has improved the health care system. Scientists and inventors release new ideas and devices which renovate the field of health care.

Health care system has become one of the basic requirements of human life. It has been thought of as a different field from electronics and information technology (IT). However, twenty-first witnessed the concept of interdisciplinary fields in which different fields are merged together to produce the beneficial and efficient artifact. Medicine has been merging with engineering, physics, biology, and mathematics thereby introducing a new major field of study known as Biomedical Engineering (BME) which was introduced in the 1970's. BME is a multidisciplinary field based on the application of engineering principles to the field of medicine. [1]

There are many subdivisions in BME, one of them being telemedicine. Telemedicine is derived from two Greek words tele means far and medicine. It is a combination of telecommunication and medicine fields. Telemedicine is thought of as long-distance clinical health care, including practitioner-to-patient meetings, practitioner-to-practitioner discussions and exchange of clinical information via Internet technology using audio-videoconferencing equipment. E-Health (or telehealth) is a relatively recent term for the healthcare practice supported by electronic processes and telecommunication. [2]

This is the thesis report of International Masters degree program of Biomedical Engineering. The thesis work has been performed with the Telemedicine Laboratory of Tampere University of Technology and the Etelä-Pohjanmaan Terveysteknologian Kehittämiskeskus ry located in the MediWest Technology Center in Seinäjoki.

This report is divided into seven chapters. The first is the introductory chapter; the second explains basic concepts of elderly care and telecommunication technologies that are involved in the manufacturing of tracking devices; the third is about available tracking devices for elderly care; the fourth is about the experience of experimenting with the devices that are manufactured in Finland; the fifth is about the implementation

of online database websites concerning available tracking devices; the sixth is the results of the survey and discussions about tracking devices, and finally, the seventh is the concluding chapter.

1.2. Aims of Thesis

The main theme of this thesis is to discover the solution that makes the life of elderly people independent and easier to perform their daily life routine. Aging is one of the major problem that increasing dramatically in all over the world. It can become highly difficult for a family member or a nurse to look after a dementia patient twenty-four hours a day. The patient may feel a loss of privacy in this situation and hence may feel as if they are dependent on others.

In order to evaluate various ways to improve the lives of elderly, this thesis begins with evaluating tracking devices. Though tracking utilities have been present in the past in products such as vehicles, RFID tags for animal monitoring, and trackers for courier parcels, now there is a focus on the development of different tracking devices for the elderly. The concept of tracking devices has already been introduced for dementia patients. As a result the patient does not need continuous monitoring by a relative or a nurse. Furthermore, multiple patients can be monitored simultaneously from one locale through the use of computer technology. In the case of an emergency or an accident, there is a system specifically developed to alert the relevant person.

In this thesis, the tracking devices are studied that currently available or forthcoming in consumer market. Then remarks are provided on the performance of some devices, which were noted during testing phase. After that there are the results of a questionnaire survey that was conducted for different users to obtain their opinions about the usage and usefulness of the devices. This survey was highly beneficial to the research and the further development of the tracking devices. Following this is the description of the development of a web application which has information about all the tracking devices. Different links have been provided for more information including methods of purchasing these devices.

This area of research can be extended into the doctorate level as there are many ideas to enhance the research done in this field. For example, it is possible to merge many other medical devices with these tracking devices or even remotely monitor patients through the use of computers.

CHAPTER 2

Background

- Necessity of Elderly Care
- Dementia and Alzheimer's Disease
- Tracking Devices Technology

2.1. Necessity of Elderly Care

According to the United States survey by the Center for American Progress, there were 34 million elderly Americans in 2007 and this number was predicted to increase to 80 million by 2050 [3]. In Europe, it is predicted that people over 65 will make up one-third of the population by 2050. [4]

According to the statistics that estimates the existence of roughly 60 million elderly people now and 125 million by 2050 in Europe and North America. Consequently, the requirement of careful medical treatment for the elderly is necessary. This is a rather immense issue now that needs urgent attention. Otherwise normal hospitalization and nursing systems will be under tremendous pressure if forced to handle such a large number of elderly patients. The inventions of computers and super-computers have helped in many ways, for example the remote access, monitoring, control, and management of individual PCs in an organization. Based on the same notion, the need for such a system was felt in the possibility of providing a way to look after a number of elderly patients at a time. It had to be some type of high-tech device that would be able to monitor more than 100 patients at a time. In cases of emergency, be able to generate alarms or signals to alert the nurse or care taker of the patient.

Consequently the research work in the field of elderly care devices started a decade ago, in which the possibility and implementations of such devices were investigated. After the evaluation and the realization of the enormous benefits of such devices, development work began and continued on for the last two to five years. At present, these devices are implemented, and their services are provided on a limited basis. Due to the invention of home care devices, pressure on nurses and also the patients has been reduced. In addition, the amount of patient visits to a hospital has been cut down providing ease to care takers and hospital staff.

2.2. Dementia and Alzheimer's Disease

Usually there are two common diseases faced at old age known as dementia and Alzheimer's disease. Dementia is not itself a specific disease but a group of disorders that occur in the brain at an old age or sometimes earlier in cases of accidents. The major effects are mainly the loss of intellectual abilities such as memory loss, or mental deterioration of functional source. [5]

These patients lose control of their thinking ability and forget daily life routine work such as eating, sleeping, dressing, and/or even their sense of direction. The disease also has an effect on an individual's mood and personality. Unfortunately, most patients do not even realize that they are experiencing the problems of dementia. Other than aging, dementia can also be caused by a head injury, brain stroke, brain tumor, destruction of brain cells, or hereditary reasons. [6]

Alzheimer's is a form of dementia in which a person's mental capacity decreases as an effect of physical changes to their brain. Brain cells are damaged and do not repair accordingly. The most common and visible symptoms include memory loss, difficulty in daily life routine tasks, loss of interaction, loss of sense of direction, and wandering during the night including sleep walking [7]. These patients require a lot of attention, and it is necessary to watch their every movement. So the tracking devices play a crucial role in the well being of these patients. Nowadays this kind of devices is also used for locating the right direction by air, on road or by sea [8].

The tracking devices will help the patients in remembering daily life routine tasks and help their caretakers to respond to them in any case of emergency. The most required tracking devices are home care devices which are currently available in the market. Home care devices are a successful solution for patients of Alzheimer's or dementia who need the attention of a caretaker or nurse twenty-four hours a day.

2.3. Tracking Devices Technology

2.3.1. RFID

Radio Frequency Identification (RFID) is the method of identifying unique objects using radio waves. RFID is an automatic detection method based on storing and retrieves information using RFID tags or transponders. The technology needs some level of collaboration of an RFID reader and an RFID tag. RFID tag is the hardware object that can be used for different products, such as, expensive items, animals, or persons for the purpose of identification and tracking by using radio waves frequencies. As an example, in stores in shopping malls, different items have such tags for keeping the track of items. Those tags get deactivated after the purchase of an item, or in case of unauthenticated exit from the store that tag will send an alert signal to the authorities.

RFID tags consist of two parts, first part is the integrated circuit (IC) for storing and processing the information, modulating or demodulating a radio frequency (RF) signal,

and the second part is the specialized hardware for transmitting and receiving the signal [9]. Most of RFID tags come in three common varieties named Passive, Active (Semi-passive) and Beacon.

Passive tags are the simplest tag that does not need any power source, thus named as passive RFID devices. There is small amount of current induced by incoming RF signals to power up and transmit the response. In passive tags, there is specialized antenna which is designed so to collect both power from the incoming signal and to transmit the outbound signal. Passive tags have practical read distances ranging from about 11 cm with near-field, up to approximately 10 meters with far-field and can reach up to 183 meters when combined with a phased array. Mainly, the reading and writing depend on the selected RF and the antenna size and because of simpler designed in passive. They are also appropriate to manufacture with a printing process for the antennas. The lack of an onboard power supply means that the device can be small. This kind of tags is usually used for low frequency tags. [9, 10]

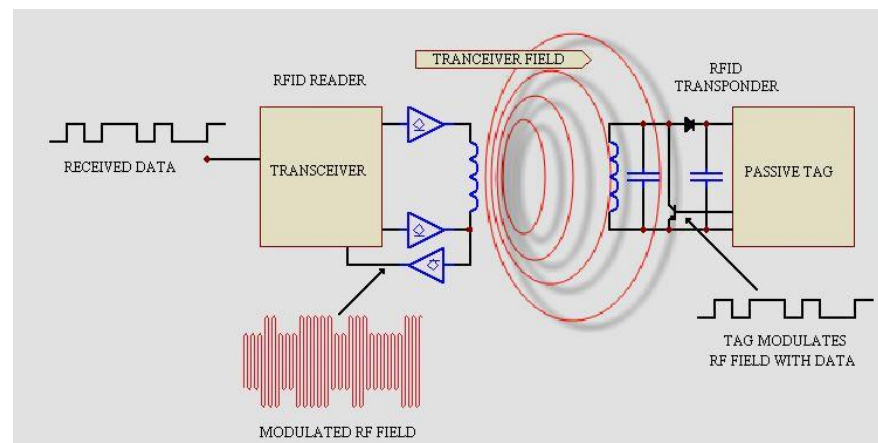


Figure 2.1. *Passive RFID* [11]

Active (also called Semi-passive) tags required the power source which is used to power the ICs and to broadcast the response signal to the receiver. Power source may be generally a small battery. Active tags communication is usually much more reliable than passive tags due to the ability for active tags to conduct a session with a receiver. A lot of active tags today have operational ranges of hundreds of meters, and a battery life from several months to 10 years. Active tags may include larger memories than passive tags, and may include the ability to store additional information received. Active tags are widely used in the manufacturing of home care and tracking devices. [9, 12]

A beacon tag is another kind of RFID tag in which this tag transmits autonomously with some fixed number of blink pattern and do not take action to interrogation. [9]

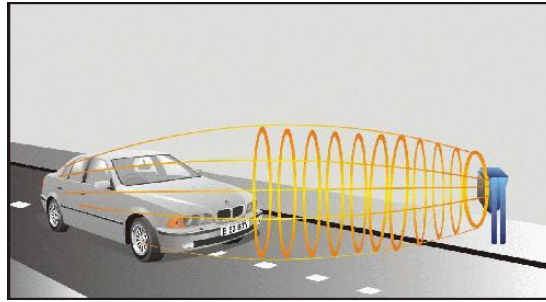


Figure 2.2. *Active RFID* [13]

There was an experiment of RFID implants conducted by British professor of cybernetics, Kevin Warwick, who successfully implanted a chip in his arm in 1998. The Food and Drug Administration (FDA), an agency of the United States Department of Health and Human Services has approved the use of RFID chips in humans in October 2004. [9]

VeriChip is the first FDA approved human implantable RFID microchip introduced by VeriChip Corporation. According to the company, the 134 kHz RFID chips can integrate personal and medical information and enables safe transfer of medical information during the hospital visits. [14]

Human tagging and tracking could be useful in hospitals, especially emergency rooms. A nurse or doctor could easily access patient history or information concerning previous treatments or hospital visits. [15]

2.3.2. GPS

Global Positioning System (GPS) is the newly emerging tracking and route planning system is the Global Navigation Satellite System (GNSS) developed by the Department of Defense (DoD) of the United States. GPS is a satellite technology uses a constellation of between 24 and 32 Medium Earth Orbit satellites that transmit precise microwave signals that enable GPS receivers to determine their current location, the time, and their velocity. The GPS satellite constellation is managed by the United States Air Force 50th Space Wing. [16]

GPS is widely used by non-military or public sector as a navigation system specially vehicle tracking and navigation purposes. At present a GPS tracking unit is a device that uses to find out the exact location of an object, vehicle, person, or other assets and to record the position at regular intervals. All the position is stored regularly and may be transmitted either to some central database location or send by Internet connection to the computers using General packet radio service (GPRS). The accurate information can be extracted by available customized software or web services provided by different companies.

Nowadays most of the tracking devices available in market is based on GPS receiver chip embed in it because GPS technology is the cheapest solution among other ways, therefore 75% of tracking devices built by using GPS receiver chip [8, 17]

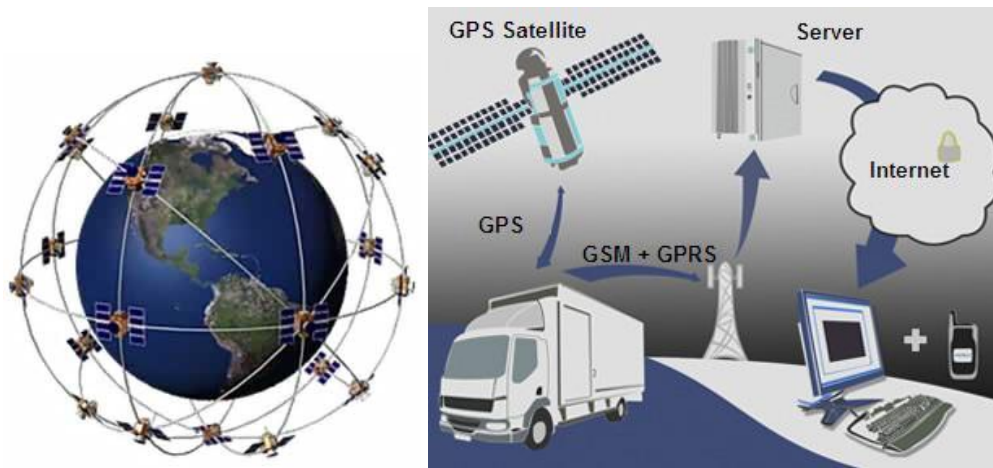


Figure 2.3. (a) GPS Satellite [18] (b) How GSP System Works [19]

There are different kinds of GPS Tracker (or GPS receiver) designed for different purposes and consists of three categories, data logger, data pusher, and data puller. GPS data logger is keeping a record of the positioning of device at regular intervals. This data record is either saved in internal memory or internal flash memory. Later, this data can be transferred into computer via USB port for further analysis by using customized software. This kind of device is suitable for sports activities especially for athletes to measure distance and time. Also it is beneficial for elderly care to keep the record of patient, where they are going and how long they remain out of the premise etc. In home care GPS devices, data logger is important to record the patient history and must be saved on regular basis. [17, 21]

GPS data pusher is of the most important for tracking devices for elderly care and this kind of devices also used by the security service providers. In data pusher devices, the device can be locate at regular intervals of time and determine the server that can instantly analyze the data. The falling prices of the SMS and smaller sizes of mobile phone permitted the integrate technologies. A GPS receiver is embedded in the latest mobile phones and at regular intervals of time, the phone sends a text message via SMS having the information from the GPS receiver. Some corporations provided data push technology which enable the GPS tracking for elderly care. These devices started to become common and cheaper simultaneously as mobile phones. The applications of these kinds of trackers include Animal Control in which monitoring and locating them in case of lost, Fleet Control for instance a courier company put such a tracker in their vehicles that allow the staff to know the direction and time of delivery, Stolen Vehicle Searching in which hidden devices installed in the vehicle to locate via SMS or security company in case of theft. Based on the mentioned benefits, a system called IP Nursing System uses the same technique to keep a track of their patients. [17]

Data puller device is opposite to a data pusher, these devices are always-on and can be queried as often as required (pull technology). These can be used in the case where the location of the tracker will only need to be known occasionally e.g. placed in property that may be stolen. These devices are coming in the form of GPS receiver and

a cell phone, when sent a particular SMS reply to the message with their location. [17, 20]

2.3.3. GSM

GSM stands for Global System for Mobile communications which is the world's most popular standard for mobile phones. Currently more than 3 billion people across the 200+ countries using this technology. GSM is 2G (Second Generation) technology while currently 3G (Third Generation) is also started but it takes time to shift from 2G or 2.5G to 3G technology. GSM mobile phone provides several features including international roaming, SMS, and usage of Internet via GPRS (General Packet Radio Service). GSM is the complete infrastructure setup consists of Base Station, Base Transceiver Station, Mobile Switching Center, Network and Switching Subsystem. These are the main core of GSM while numbers of subsystem are also the part of GSM technology.

GSM is an important part in designing of elderly care devices because it is the main communication channel between device and care taker of patient. In mobile phones and elderly care device, a SIM (Subscriber Identity Module) card is inserted which contains the specific number and information of user. The use of GSM in case of elderly care is so that in emergency situations the alarm signal will be send by SMS and some devices will be having voice support to talk to the patient directly. [22, 23]

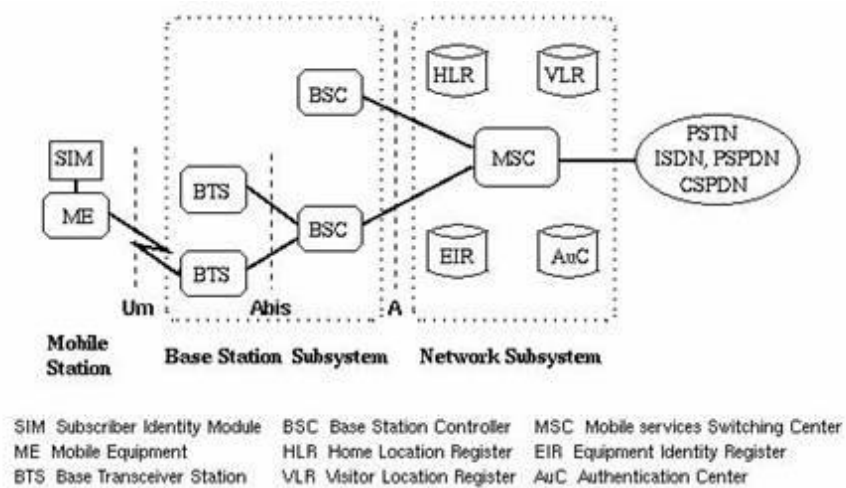


Figure 2.4. GSM Network [23]

2.3.4. GPRS

GPRS stands for General packet radio service. It is the data transfer technology which is packet oriented mobile data service that works on GSM network. GPRS is 2.5G technology comes after GSM. By the adoption of GPRS in GSM technology, GSM mobile phone service provider announced more features in handsets such as Multimedia Messaging Service (MMS), Push To Talk (PTT), Instant Messaging (IM),

Internet application that is Wireless Application Protocol (WAP), and Point-to-Point (P2P) services.

This is also an important service in the development of elderly care, in this service the data will be received via GPS and will then be transmitted by GPRS to the end user. For example, a web application that gathers information about the patient and will notify the nurse about the current location of patient, this process is carried out via GPRS. [24, 25]

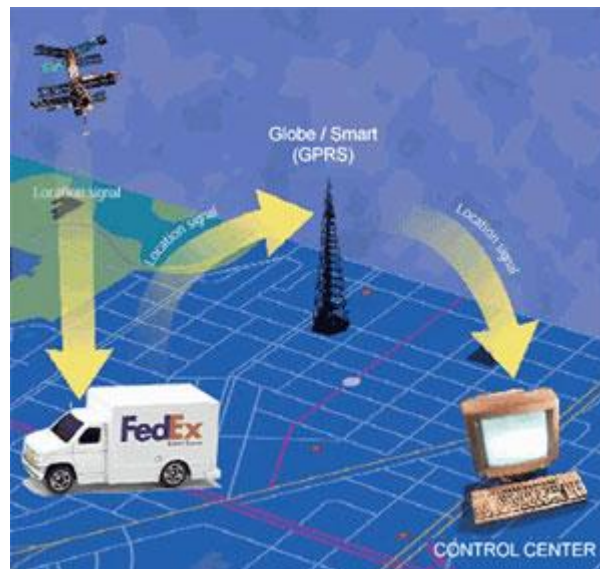


Figure 2.5. *How GPRS Works* [26]

CHAPTER 3

Exploring the Tracking Devices for Elderly Care

- Introduction
- Survey of Tracking Devices
- Existing Tracking Devices
- Promising Technologies in Elderly Care

3.1. Introduction

The telecommunication technologies explained in the second chapter are widely used in the manufacturing of tracking devices for elderly care. The main focus of this chapter is about the sort of research work that has been done or that is currently progressing related to tracking devices for the elderly. In addition, the chapter discusses what kinds of tracking devices are available in the market for elderly patients.

Research work requires previous and background information. Before starting research on a particular topic, literature review is the most important tool to know about earlier work progress in that area of research. It also gives an insight into both pros and cons allowing an analysis for the possibility of further work.

In case of tracking devices, research work is successfully continuing because of availability in telecommunication resources. The development of telemedicine is directly relying on telecommunication technology. Hence for the development of tracking devices, telecommunication plays an important role.

3.2. Survey of Tracking Devices

For the purpose of survey about tracking devices, there were different databases of research articles explored, and more than 60,000 research papers were found about all the different kinds of tracking or monitoring devices. There were 18,000 papers about different tracking devices that could be used for humans or animals, and less than 100 research articles were related to tracking devices for elderly care. There were two papers published within 2006 and 2007, fifteen papers during 2008 and seventeen papers in 2009 up until the 31st of July 2009. [27]

This means that research work about tracking devices has been increasing day by day. A brief research summary about adoptability of tracking devices that has been seen

in the last two years in a comprehensive research paper, named “Attitudes of family and professional caregivers towards the use of GPS and RFID for tracking patients suffering from dementia,” is written regarding statistics of tracking devices [28]. In this research, there is a discussion on the issues about adoptability of technology into elderly care, the topic of caregivers willing to support the use of GPS and RF tags in medical devices, patients willing to use devices, and pros and cons for the future of tracking of patients via GPS and RF tags. One of the biggest fears about these devices is the reduction of human interaction between the environment and old people. Some main factors found out about using GPS and RFID tracking devices for dementia patients:

- Independency of patient
- Devices designed for relaxation of caregivers
- Patients’ safety feature is important
- Support of device

In this study, researchers deduced that family caregivers showed higher support for the use of GPS and RFID tracking devices instead of hiring professional caregivers for the safety of the elderly people. Both family and professional caregivers agree on the point that the caring of dementia patients via GPS tracking devices is internal family matter. Family caregivers emphasized that tracking devices must be simple and user-friendly. Furthermore, the future of medical devices with GPS or RFID is bright and more research is required to enhance the quality of the devices and make them as simple as possible. [28]

3.3. Existing Tracking Devices

3.3.1. Miratel

MIRATEL OY, Finland is a company that providing a comprehensive solution for elderly care named Miratel Innova (IP Nurse Call System). This system is connected with Innova wireless or wired devices having nurse call environment for nursing homes and hospitals based on IP technology. This product provided the standard open network cabling, self-monitoring system with automatic technical alarms, standard compliant connectivity like HL-7 support, operates on routed networks and support for clustered databases. Miratel Innova nurse call system increase the quality of patient care, staff productivity and improving efficiency in the provision of treatment. [29]



Figure 3.1. *Graphical Design of IP Nursing System [29]*

3.3.2. Emfit Sensors

Emfit Ltd is a company that producing the Emfit Movement Monitor, Emfit SafeBed, Emfit SafeFloor, Emfit SafeDoor, and Emfit DVM (Discreet Vitals Monitoring). [30]

The Emfit Movement Monitor is a new technology for monitoring an individual during sleep may experience certain types of movements which a nurse or family member should be alerted. This new sensor technology detects every movement of patient including micro movements caused by breathing and the heart beating. Embedded software detects when a certain movement's frequency is higher than 2.5 Hz or 3 Hz, triggering a time count. If there are no movements for five seconds or ten seconds, the system will give warning. It is designed for common use and currently available for sale in the USA and Canada only.



Figure 3.2. *Emfit Movement Monitor*

Emfit SafeBed is also a new bed monitoring system for falling and wandering prevention. It consists of a monitor device and under-mattress bed sensor. It is an

absolutely undetectable as it is installed under the normal mattress. It has an audible alarm with adjustable volume and dry-contact output for connection to nurse call or personal response systems.

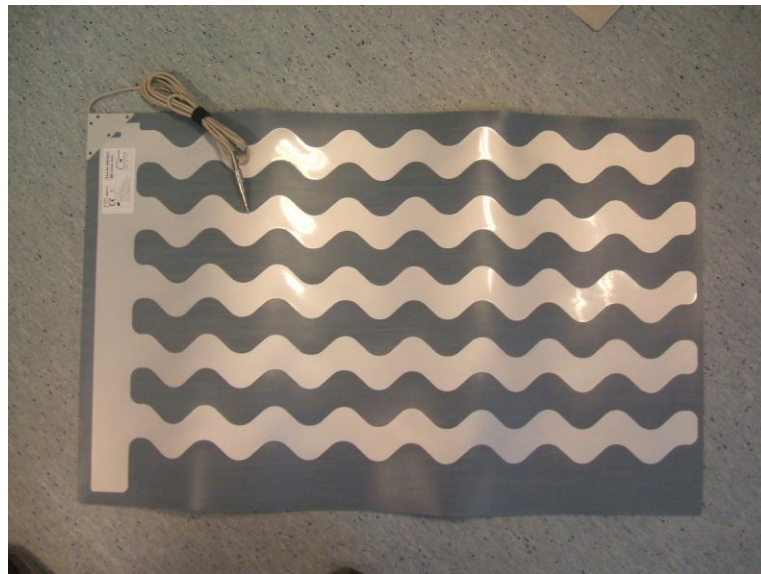


Figure 3.3. *Emfit SafeBed Sensor*

Emfit SafeFloor is a high-tech alarming system for falling and wandering prevention. It is specifically designed for a person who is unable to summon help unassisted. Floor sensor is thin and installs on the floor beside the bed. The monitor has both an audible alarm with adjustable volume and dry-contact output for connection to nurse call or personal response systems.



Figure 3.4. *Emfit SafeFloor Sensors [31]*

Emfit SafeDoor is a smart door monitoring system specially designed for people with dementia. It is a discreet and intelligent door monitoring system that monitors the door and alarms to the caregiver in case of wandering or the patient left the door open. The monitor device has both audible alarm and dry-contact output for connecting to existing nurse call system.

Emfit DVM is the latest modern IP-based system for centralized monitoring and processing of bed-specific nurse-call alarms, bed exits, and movements. Emfit's DVM technology measures basic physiology passively from below the patient's mattress

without any electrodes, leads, cuffs or cannula. This technology is consists of Emfit's patented thin film dynamic sensor, a control unit that uses advanced digital signal processing, a standard data network that serves as the media for all communications, one or more monitoring computers with Emfit's sophisticated DVM software. The system transmits all kind of information and alert messages on a standard data network by using standard IP protocol. [30, 31]

3.3.3. Mimas Pro

Mimas Pro is a GPS tracking device includes phone call alarming facility via GSM technology. This device is available in Sweden at Communication Dynamics who are official distributors of Mimas products [32]. There is group of companies in Finland named G-S Group in which of one sister company named "Global Safety and Security Solutions Ltd" (GSSS) designs, manufactures and markets wireless information transmission, surveillance and tracking devices [33]. The size of this device of the device is 12 x 6.1 x 3.2 cm and weight is about 120 grams. The technical specification of this device is GPS (SiRF Star III, omni-directional Helix-antenna), GSM, Integrated antennas, and SMS communication also possible to alarm the caretaker via GPRS. Remember from this device phone call can be made only to one person because it is designed for alert someone instead of mobile phone functionality. Mimas Pro is designed for multiple purposes including elderly tracking, children and sick people, outdoor workers, wanderers and hunters. [34]



Figure 3.5. *Mimas Pro*

3.3.4. Mimas Lite+

Mimas Lite+ is the simplest device which enables to call for help with a single push button. When the alarm button is pressed Mimas Lite sends an alarming SMS to

predefined receiver and they can communicate. This device is made of just using GSM mobile phone technology only. The size of device is 5.1 x 7.3 x 2.5 cm and weight is 80 grams. There is new feature included in Mimas Lite+ in which integrated movement detector is used for sending an alarm if the user has been immobile for long time. This device is also good for elderly people, guards, nurses and children. [33]

3.3.5. Everon

Oy Exrei Ab is providing the Everon personal safety applications. Everon is a new ultra-modern wireless alarming and monitoring system that is “always-on”. The Everon system is of the best daily caring system for elderly, home patients and the disabled people brings the secured safety of a nursing home to a person’s home. The Everon Base Station is an autonomous unit. Simultaneously with a wireless alarm wristband, it features the normal care phone. The Everon system’s door sensors and base stations can locate staff, visitors or residents in case of an alarm or for security reasons. Everon system can also limit the exit or access of people individually and flexibly, based also on time limits.



Figure 3.6. *Everon wireless alarm and monitoring system [35]*

3.3.6. Vega

Everon manufacturer introduced a new GPS bracelet for dementia’s patient named Vega. This device is made up of GPS receiver, GSM, and RF tag. One of its unique features that distinguish from other tracking devices is that the specific area zone can be defined in which patient can be walk. If patient goes outside from that zone then automatic alarming signal is generated for caretaker. Also online monitoring is possible via web, and caretaker can see the exact location of patient via GPS coordinates send by the device thought GSM to the Everson web server. Another important quality of this device is the RF home base alert system that indicates the patient is at home or not. [35, 36]



Figure 3.7. *Vega GPS Bracelet*

3.3.7. ArctiCare System

ArctiCare Technologies Oy is providing the “ArctiCare Senior Care System” which is the easy way to care elderly people at home, and in case of emergency this system generate the alarm to alert the caretaker. The ArctiCare system consists of a computer unit at home for analyses the security parameters and if the parameters have been violated then automatic alarm function alert helps. The alarm is directed to the nursing home's monitoring place or to the local emergency services and it is pre-routed to go first to a family member or caretaker or a security company personnel. The alarming message can also be transferred to the health care representative who can assess the required help. The patient can also contact to the nurse by computer system, and communicate via videoconferencing to discuss any kind of problem on real-time basis. [37]

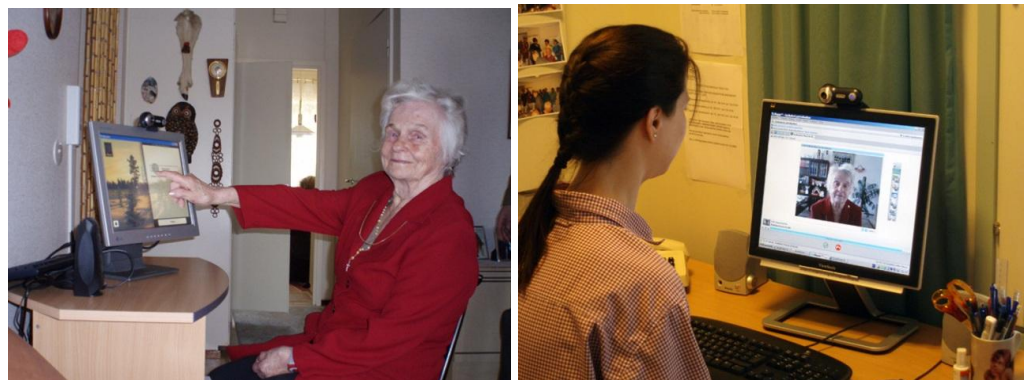


Figure 3.8. (a) *ArctiCare, Patient contacts nurse* (b) *Nurse helps patient* [38]

3.3.8. eHIT Home Care

eHIT Oy is providing the integrated seamless and real-time patient-doctor communication system with the patient’s medical record and previous nursing support. This communication system uses eHIT’s Health Gateway that is an effective and secure

channel which transfers data from different measurement devices to the doctor via mobile platform and wireless networks. Health Gateway provides patient and nursing solutions that guaranteed the available measurement results are accurate, and cost and time effective. [39]

3.3.9. Keruve

Keruve is a Spanish company that manufactures Keruve GPS Locator. It consists of two parts at user end; one is wearable bracelet having GPS receiver and GSM modem, and other is GSM puller device to see the location of bracelet (or patient). The GPS Tracker bracelet is waterproof and can only be removed with a special tool so that there is no chance to drop-down the bracelet by patient. [40]



Figure 3.9. *Keruve GPS Locator*

3.3.10. Win Health Sensors

Win Health Ltd. is a Scottish company that developed Hip Saver Hip Protector and FallSmart Bedside Fall Mats. Hip Saver Hip Protector protects weak elderly people from the effects of falling, and provides great shock absorption. This sensor has been separately tested at two prestigious Universities, Harvard University, Massachusetts and Tampere University, Finland.

FallSmart Bedside Fall Mats can help to prevent injuries, when patient intentionally climb over bed rails or accidentally fall out or roll out of the bed. When placed on the side of a bed, it provides a soft and a force attenuating surface that absorbs the impact of the fall. [41]

3.3.11. Leadtek

TrackStick, a UK based company is producing the Leadtek LR8M03 LBS that is a small and powerful GPS tracking device which is developed for personal remote

positioning and emergency reporting. It is suitable for multipurpose for example kid and elderly tracking, or vehicle security. LR8M03 is not only transmitting the longitude and latitude coordinate to mobile by SMS but also transmitting to PC via GPRS and then displaying the location by specific map software. There are four quick dial buttons for the dialing to preset numbers, and with the superior sensitivity GPS chip on hand. Users can also take benefit from its compact size, lightweight, as well as long working hours. Also the track data can be downloaded to Google map for quick monitoring purpose. [42]



Figure 3.10. *Leadtek LR8M03* [42]

3.3.12. Brick House GPS Devices

Brick House Electronics made the P-Trac Pro GPS+ Tracking Device that is one of the simpler and smaller tracking device with a seven to twenty-one days battery life. The special feature in this device is that it works perfectly inside the buildings. Currently, this device is only available in the United States.



Figure 3.11. *P-Trac Pro GPS+ Tracking Device* [43]

Another device named P-Trac Micro is the real-time GPS tracking device using A-GPS (Assisted GPS) and it can also works inside the buildings. This device is perfect for tracking the assets or elderly people.



Figure 3.12. *P-Trac Micro* [43]

M-Trac Pro Personal GPS Tracker is a good device to locate elderly person, child or any other item. If a child or an elderly person is lost then this device helps to the family with a panic button that reports their location in case of an emergency. [43]



Figure 3.13. *M-Trac Pro Personal GPS Tracker* [43]

3.3.13. Live View GPS Products

Live View GPS is a company that provides different types of GPS devices which used for security systems, vehicles tracking, elderly or child tracking, as well as asserts tracking. These devices have GPS receivers that will receive position data from the GPS satellites. They also have SIM card that transmit the GPS position data via a digital cellular network. The information is ultimately sent to a server where the GPS data information is received. Typically, these servers integrate the received GPS data, along with mapping software to show the devices position. Let see the devices that used for health care purpose.

Live Trac PT-10 is the simple GPS Tracker. Unlike other GPS trackers it updates every ten seconds when traveling over 16 km/h or every 20 feet when walking. It can

be use for track a child, an elderly or even vehicle. The PT-10 is the GPS tracking device that can be use everywhere in the world.



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Figure 3.14. *Live Trac PT-10* [45]

Covert GPS Tracker PT8100 uses high-tech tracking technology whether need to locate a child, person, or asset. With a seven to ten days battery life, this GPS Tracker can be tracked indoors and in other covered places where conventional GPS devices fail. It is the ideal device for covert operations and uses it to protect valuable merchandise and equipment, locate elderly patients.



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Figure 3.15. *Covert GPS Tracker PT8100* [44]

Covert GPS Tracker PT8200 is a wireless asset tracking beacon specifically designed to meet the needs of business owners with high value assets that are at risk of being stolen. It uses up to date location technology and is ideal for people or asset tracking applications. It is a small, has a long battery life up to 30 days. It can be used to track just about anything that moves, and can be located indoors.



Figure 3.16. *Covert GPS Tracker PT8200 [45]*

Enfora Mini MT GPRS Tracker is a slim and compact tracker device takes personal and professional tracking. This is a portable device, can be used easily and does not require any kind of installation. The Enfora Mini MT's has 1340 mAh internal battery that keeps it powered for about 8 hours. This device can also be worn on a belt clip or even placed in a purse or backpack.



Figure 3.17. *Enfora Mini MT GPRS Tracker [45]*

SPOT Satellite Personal Tracker gives a vital line of communication with friends and family whenever required or in case of emergency help. This device is compact, strong and easy to use and because of satellite technology, it works virtually anywhere even where cell phones do not work. [44, 45]



Figure 3.18. *SPOT Satellite Personal Tracker [45]*

3.3.14. B-COM Security System

B-COM Security is the United States based company providing emergency call systems. B-COM offers a variety of emergency call systems that are designed to elderly care needs. Applications include elderly day care and medical offices setup, computer based nurse call and emergency systems. [47]

3.3.15. Coban GPS Tracker

Coban Group Co., Ltd is China based company manufacturing the Coban GPS Tracker. Model GPS/GSM/GPRS Tracker (TK-102) is the product can locate accurately and be used in guarding vehicle against theft, protecting child, elderly disabled, pets, managing personnel and tracking criminals secretly. It works on existing GSM 850/900/1800/1900 MHz networks and GPS satellites. This device can locate and monitor any remote targets by SMS, Computer or PDA. [48]



Figure 3.19. *GPS Tracker (TK-102) [48]*

3.3.16. GPS Walker

GPS walker for elderly is designed by group of student researchers in Arnhem Nijmegen University designed the GPS walker that has been tested on some patients of

nursing homes. The experimental place for this effort has been Betuweland nursing center in the Dutch village Bemmelen, Netherlands. The system was particularly aimed at people with amnesia or orientation problems. The researchers aimed to avoid the common incidence of elderly people getting lost even within their old houses. The instructions for GPS walker are easy to invoke, there are just five different buttons each intended for a different use. Once the user presses a button on the device the walker points out the way for instance push of a coffee button tells the way to the restaurant. [49]



Figure 3.20. *GPS walker*

Table 3.1 shows the summary of all devices with respect to their technology used.

Table 3.1. *Properties of Devices*

Device	GPS Device	RFID Device	Application System
Miratel			√
Emfit Sensors		√	√
Mimas Pro	√		
Mimas Lite+	√		
Everon		√	√
Vega	√		
ArtiCare System			√
eHIT Home Care			√
Keruve	√		
Win Health Sensors		√	
Leadtek	√		
Live View GPS	√		
Cobon GPS Tracker	√		
GPS Walker	√		

3.4. Promising Technologies in Elderly Care

3.4.1. Hi-Tech Sensor Bed

Sophia Antipolis is a technology park northwest of Antibes and southwest of Nice, France. Here Accenture's facilities provide a test bed for a number of developing technologies that could aid older people by allowing them to remain at home instead of depending on expensive hospital care. Other developing technologies include an RFID equipped medicine cabinet that can warn users if they have picked out the wrong medication. By using a digital camera and facial-recognition software, the cabinet can provide more information and serve multiple users. [50]

3.4.2. Locomotion

Locomotion is an organization that uses GPS integration with mobile phones called the Locomotion System. Locomotion offers users greater independence and mobility by helping the elderly and other people who suffer memory loss to overcome their fear of leaving their houses by helping them comeback safely. The system allows them to have an electronic aide at their side that can put them in contact with a carer at anytime which allows them to be watched constantly. Monitoring is performed by a call center that employs a web-based application to manage interaction with users' mobile devices. The software includes an automatic calling feature to contact the users periodically to check if they are well. Their response allows those in charge to know everything is okay, and if not, to know about it immediately. [51]

3.4.3. Elderly Mobiles

Previously GPS technology was expensive to use for home based devices, but now GPS tracking devices are available cheaply along with mobile phones. Motorola and Blackberry were the first GPS-enable phones to be available in the United States. Initially, Motorola "iDEN" phones were commonly used for employee tracking on the business-oriented Nextel network. After that Blackberry started employing GPS which was used exclusively by corporate and government officials. Next specialty devices were produced under the names of "Disney Mobile" and "Wherify Wireless" targeted for use by children and the elderly. [53]

3.4.4. RFID in Homes

RFID technology can improve healthcare technology for elderly patients. Researchers have built two new systems that use RFID tags to monitor elderly patients in their own homes. At Intel Research Seattle and the Georgia Institute of Technology researcher has given optimistic feedback about the use of RFID tags for home based monitoring for the elderly. RFID tags emit a radio signal that can be picked up by RFID reading devices. In Georgia Tech's Memory Mirror uses RFID readers are attached to medicine

cabinet shelves and beneath counters. Both the caregiver and the Memory Mirror read RFID-tagged items to keep track of their patients. [54]

3.4.5. High-Tech Devices for Elderly

Research projects have been started to study the benefits of sensors that can confirm an old person has awakened to use the restroom. There are also kitchen appliances that remind dementia patients how to use things like coffee pots. Intel Corporation has been working since April 2002 on prototypes that integrate with wireless sensors and digital devices to issue medication reminders and even determine a senior's level of activity. GE builds on existing home security systems and deploys simple motion detectors to observe for abnormal behaviors. [55]

3.4.6. RFID in Hospitals

RFID technology has many uses in health care such as locating patients, being used in critical equipment, and for medical personnel especially in large hospitals.

In the scenario of a large hospital, RFID tags work by the utilization of antenna-equipped microchips. These chips wirelessly transmit stored information to a remote device called a reader. These can be typically attached to small plastic or paper tags or may be embedded in patient's wristbands. Information about the bearer of the tag, whether it be a patient or employee, including an ID number, a serial number, name, age, or other relevant data can all be stored on an RFID tag.

By an extension of the above, it can be concluded that several possibilities exist for the improvement of RFID technology in the area of health care for elderly patients. For example, the location of an elderly patient in a hospital, whether in a lounge or a rest room, can be monitored at any time. [56]

CHAPTER 4

Performance Analysis of GPS Devices

- Introduction
- LDS Finder Device
- Teltonika HandHeld Tracker
- Questionnaire Survey

4.1. Introduction

In the previous chapter, different kinds of tracking devices that are made up of RFID and GPS technologies have been discussed, and reviewed in detail. For communication with nurse or caretaker, devices are used GSM and GPRS technologies.

Often practical knowledge diverges from theoretical knowledge. Practical information is more authentic and accurate and can be used to judge the quality of the device. Hence, this chapter goes into detail about GPS tracking devices that were tested and analyzed on their performance to discover their pros and cons.

The tracking devices tested during this diploma work, the LDS Finder (also called GTS-200) and Teltonika HandHeld devices. These devices are distributed in Finland by Location Data Systems LDS Oy and VERFI. For performance analysis, these devices were provided by EPTEK ry. These devices were selected because this thesis is a part of EPTEK ry research project which carrying out research on hardware design and performance of these devices. These devices are also available for buyer in Finland.

Location Data Systems LDS Oy, an organization in Oulu, Finland, develops person locating devices. The organization is manufacturing different types of tracking devices for patients of Alzheimer's and dementia and developmentally disabled people. [57]

4.2. LDS Finder Device

4.2.1. Description

This device is about 7.7 cm in height, 4.45 cm in width, and 2.7 cm in thickness and can be attached to one's belt or put in a pocket. The image of the device is shown in figure 3.1. This device is composed of different IT technologies including a GPS receiver, GSM modem, and GPRS service. To find the position of the device there are the options to see it on a mobile phone or on a webpage. Also the most important

feature is that the device is waterproof by using standard protection of IP-67 (International Protection Rating 67). IP-67 is defined in the international standard IEC 60529 which categorizes the levels of protection supplied against the intrusion of solid substances, including body parts like fingers, and water in electrical enclosures. [58]

The device is based on the GPS receiver which uses an inserted GSM SIM for sending messages to monitor a person. There is a red button on top of the device that can be pressed by the patient in case of an emergency.

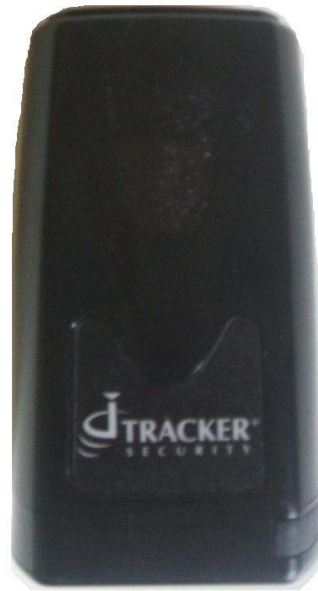


Figure 4.1. *LDS Finder*

The device consists of two parts: the hardware part that hangs (or is put into pocket) by the patient, and the monitoring part which may be a mobile phone or some real-time webpage. The hardware device itself consists of three pieces: a battery, GPS receiver and GSM hardware, and a clip shown in figure 4.2. In order to use this device, first it is configured by mobile based management software or via the web, and then the desired mobile number to be warned in case of an emergency, low battery, or when the device is powered off, is set. The device is designed to be constantly functioning thus turning off the device is not simple so that the patient cannot switch off the device accidentally. Before using the device, the battery must be charged fully which can be noted by the red LED (Light Emitting Diode) light near the power connection turning green. The next step is to insert the SIM card into the device in its respective place. Then the device is started by pressing the power ON button. The vibrator inside the device vibrates, and 3 LEDs on front blink when the device is switched on. The device usually takes one to two minutes to connect to the GPS satellite. Connection is indicated by the green light on the face of the device. If the light is red in color, the device has not detected any GSM service.



Figure 4.2. *Parts of LDS Finder*

Finally, if the green LED on the device is on, indicating that the device is ready for use, the device is attached to the belt of the patient and they can go for a walk. Then the caretaker or responsible person can see the movement of the person online at <http://service.tracker.fi/TrackerLocator/> by logging in with a specific user ID and password which is given at the time of the device's purchase. The GPS satellite and receiver continuously interact with each other and with the GSM service. The device sends information about the current position of the patient to the company's server and updates the parameter every minute.

In case of an emergency, the patient can press the red button on the top of the device which generates an alerting SMS to the caretaker's mobile phone so that the position of the patient can be checked, and caretaker can be reached as soon as possible. There are also two other important alarms generated by the device: one for low battery power, and the other for the device being turned off.

4.2.2. Method of Device Testing

The testing and performance analysis of this device aimed at observing whether it was actually functioning according to the company's specification, as well as finding out its usefulness for patients of dementia.

The area where the device was tested was about 1.25 km and which took about 15 minutes to walk. For the tests, the device would hang from a person's belt, and he would walk the distance. Before leaving, the device was checked to see if it was properly switched on, if it was receiving signals from the GPS satellite, and also if it showed the correct location on the webpage. After reaching the destination, the device was checked again on the webpage to see if it was pointing in the vicinity of the area (the position of device).



Figure 4.3. *Testing LDS Finder Device*

For testing purposes, a personal mobile number was setup with the webpage to be sent alerts when the button on the device was pressed. The purpose of this was to test how efficient the device and network to send the message were. While walking on the predefined path, the red emergency button was pressed and within a few seconds an SMS message was received on the mobile phone saying “Button Alarm”, and also an alert signal was seen on the webpage with the particular location of the device visible on the map.

Also, it was observed that after three days when the battery power was low, a warning SMS was sent to the set mobile phone showing “Low Battery Warning”, and this message was continuously received every half an hour until the device turned off. When it finally lost all power, another SMS was received saying “Device Off”, and the time of the SMS message indicated the time of the device turning off.

Figure 4.4 exemplify the webpage that shows the map which indicates the position of the device provided by the Tracker Security, Finland [59]. On their website, they have also provided some useful utilities to maintain the history of device movement and, in case of multiple devices, a way to select particular targets and observe the movement of the patient (device).

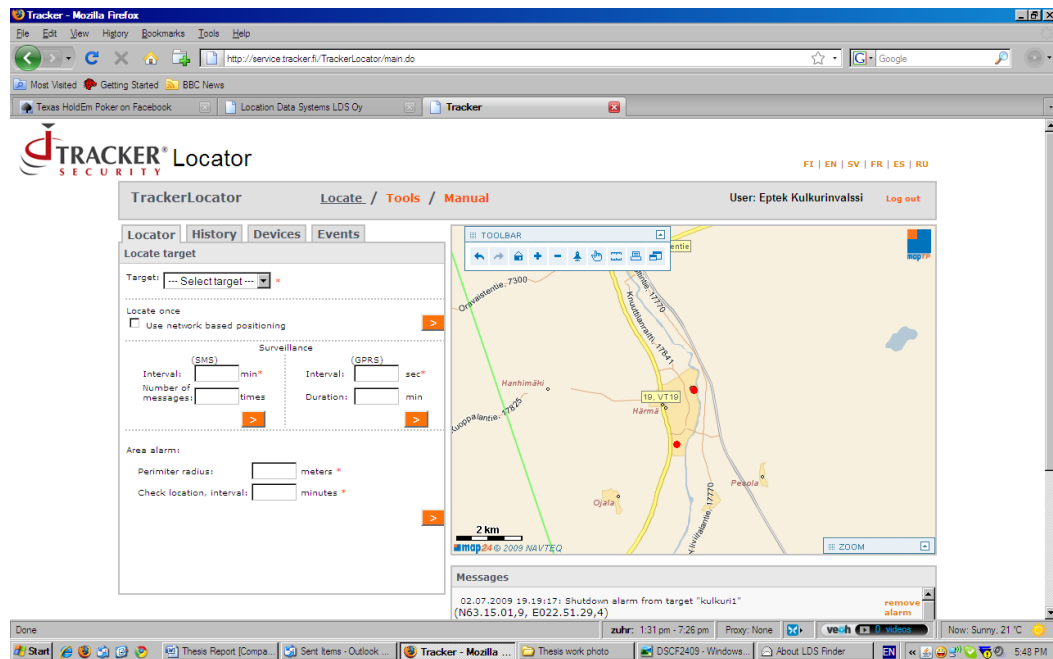


Figure 4.4. Webpage of LDS Finder by Tracker Security

4.3. Teltonika HandHeld Tracker

4.3.1. Description

This is another device for tracking purposes which has additional features for calling in case of an emergency, and it is specially designed for monitoring the elderly, children and pets. This device is even used for private vehicle monitoring purposes as in remotely monitoring one's car. For first time use, the device needs to be configured. A SIM card is installed and five phone numbers are fed to the device. These numbers are those which a person may call in case of an emergency. This device is connected with the GSM and GPS networks and transfers data via GSM network using GPRS. These networks allow data to be transferred to a caretaker's mobile phone or the web. The caretaker can also call the person in possession of the device, and on the device there the options of accepting or rejecting incoming calls.

One important advantage of this device compared to the LDS Finder Device is that it can work inside a building by using GSM signals and by utilizing its calling facility to locate the exact position of the holder [60]. The questionnaire in Appendix 1 gives a clearer idea about how patients feel about using this device and how beneficial it is for them in leading an independent life. The main features of this device are shown in the table 4.1.

Table 4.1. *Specification of Teltonika Tracker*

Weight	80 g
Dimensions	91 x 44 x 19 mm
GPS	Chipset SiRF Star III 20 channels
GPS antenna	Internal Omni-Directional
GSM	900/1800 MHz and 850/1900 MHz
GPRS	Class 10 data
Voice calls	YES
Connectivity	SMS, GPRS
Buttons	6
Alarm button	YES
LED	3 (Power, GSM, GPS)

4.3.2. Method of Device Testing

The testing of performance analysis for this device was the same as for the LDS Finder Device but with one extra feature: the calling option. This option was tested by pressing red button (emergency call) of the device which contacted the the customer support operator in about ten to twenty seconds. The operator was asked, “Can you tell the location of the device at the moment?”, and within a minute he was able to tell the exact location.

**Figure 4.5.** *Teltonika HandHeld Tracker*

4.4. Questionnaire Survey

To acquire more information about the quality of the devices, the best way was to get feedback from actual users about their experiences. Therefore, a questionnaire was one of the best options available. It is meant for those people who use this device or know more about it. A questionnaire is a group of similar questions being asked from those people who have knowledge of a particular area (or product). Questionnaires are used for research purposes in different organizations especially by different companies who conduct surveys to find the value of their products.

There are a number of ways to conduct surveys: printing questionnaires and getting it answered by users, telephonic surveys, creating Internet based surveys, etc. A survey was carried out for the GTS-200 tracking device and the Teltonika HandHeld Device which are both used for many kinds of tracking purposes such as important items, animals, cars, and human beings.

The questionnaire was written for both devices for the purpose of elderly care which provided a good opportunity to analyze the devices and draw conclusions. The survey was able to answer some intriguing research questions because research can only be possible in an area where public interest and demand is increasing with the passage of time.

A questionnaire is made and organized in such a way so that common people do not hesitate to answer the questions. It is organized in multiple choice questions, allowing the user to just select the option which they consider to be the best answer. It takes roughly five to six minutes to fill in the questionnaire about the devices; see the Appendix 1.

CHAPTER 5

Implementation of Online Database for Elderly Care Devices

- Introduction
- Aims of Website
- Development of Website

5.1. Introduction

Different devices developed by different vendors in different countries were discussed in chapter 3. Information about all these devices at one place can be useful for a patient or nurse.

For this purpose, an online database website is required which is a combination of databases and web pages. A number of software development tools are available worldwide for web development. Microsoft Access 2007 was chosen to compose the database for information on these devices because it is a user-friendly program allowing one to create their own simple database systems. Access supports a number of tables, indices, referential integrity, query interface, forms to display, and reports for printing [61]. JSP (JAVA Server Pages) was used for developing the webpage, although JSP has now been replaced by JSP.Net. JSP was originally developed by Sun Microsystems and is widely used for server-side scripting for dynamically generated web pages.

5.2. Aims of Website

The purpose of creating the website was to assist the potential user of a device (either a patient or nurse) in searching through a vast number of products. The website provides a way to look at all the existing devices which are available in the market, so that one does not have to search for individual websites which can be a hassle and cause confusion. It can simplify online research about these products for common people who are unfamiliar with the Internet. The website is a kind of online hospital management system in which current information about all elderly devices is available. The website can be a part of elderly care patients' database system.

Users can not only search through the devices on this website but also read feedback from other users, doctors, or researchers who have already used the device. These people can share their experience which can help other customers who are interested in some particular device.

5.3. Development of Website

5.3.1. First Scenario

The website that was developed can be a part of the database for elderly care devices. On the initial page of the website, the user selects a particular company name from the drop-down list of companies. After selecting the company, the user selects one of the products shown in the product drop-down list. By selecting a particular device from the drop-down list, the image of the device or product can be seen with its description and feedback from a doctor or other user.

The description box gives brief details about and web-links of the device. The feedback textbox is the data entry box where information can be added by authentic doctors or researchers that have a registered user ID and password on the site. They can add information through the textbox dubbed “Feedback by Doctor”, and anyone can add information or suggestions about the device in the textbox dubbed “Feedback by User”. All comments need to be approved by the database administrator, so that users do not enter irrelevant or spam information.

Following is the general conceptual diagram of the first scenario of the website that has been discussed:

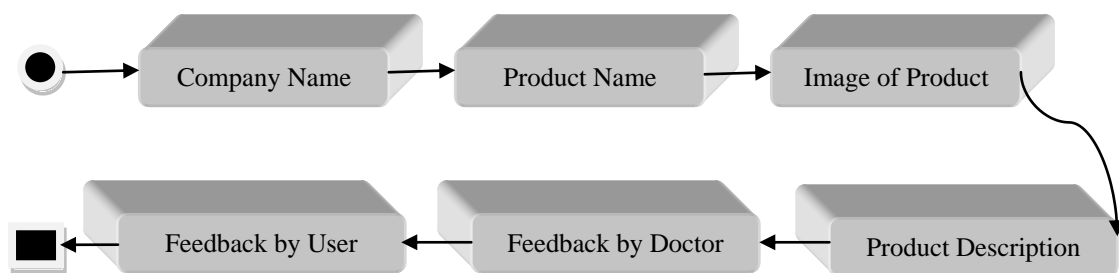


Figure 5.1. General Flowchart of database hierarchy

Now, to go into more detail about the database system, the website uses UML (Unified Modeling Language) which is the standard defined modeling language for software designing [62]. However, a database model also exists which describes the database schema specification which is how a database is structured and used [63, 64]. UML and database models are used to describe the internal structure of a database for a website. The initial step in designing a model for the database is drawing the Entity-Relation Diagram (E/R Diagram).

An entity-relation model is a database modeling procedure that shows the abstract and conceptual representation of data by producing a type of semantic data model of a

relational database in a top-down hierarchy [65]. The E-R diagram that has shown in figure 5.2 gives much more clear idea about how the website works.

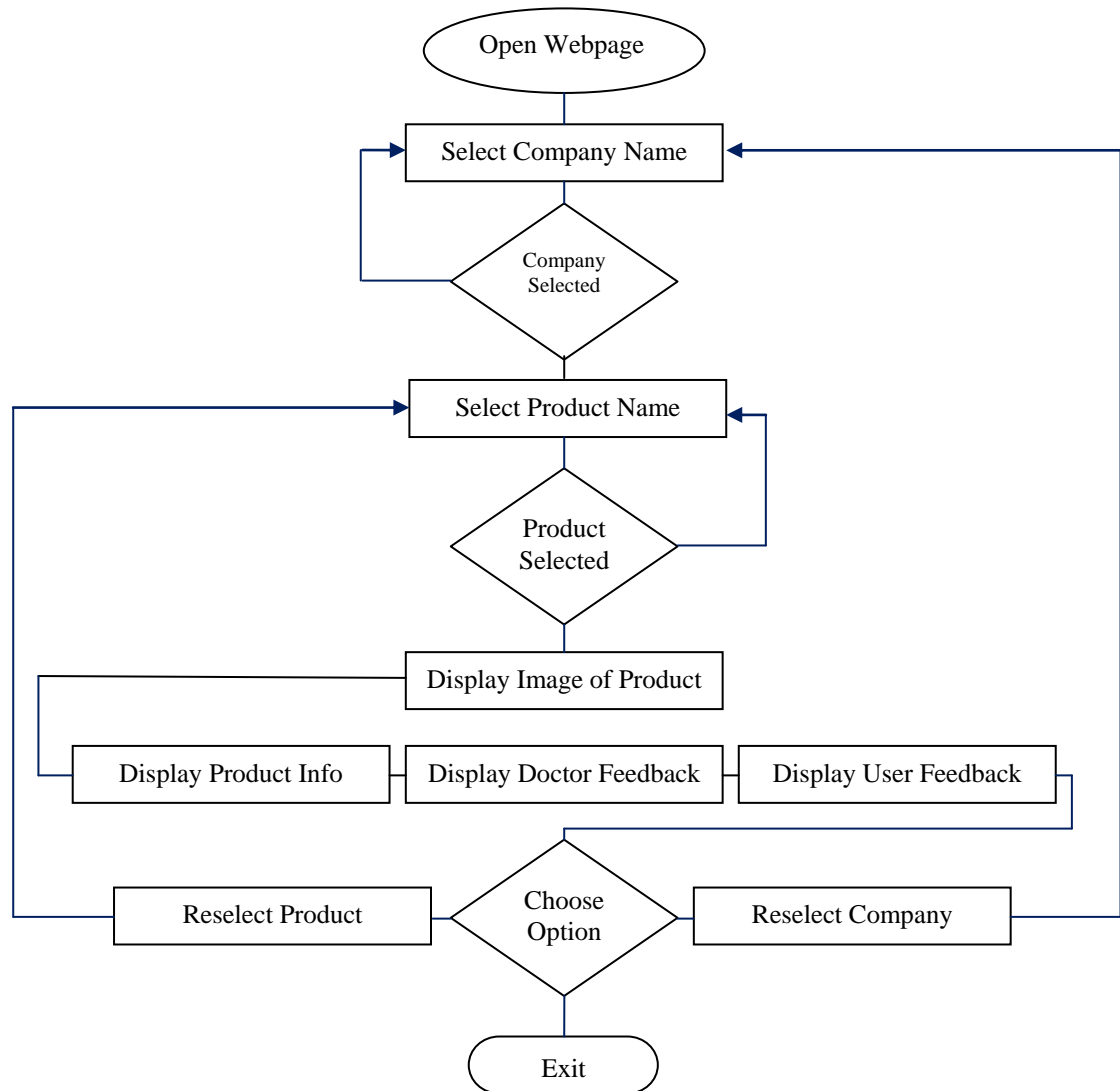


Figure 5.2. *E-R Diagram of Website*

This E-R diagram gives more detail than the general flow chart seen in figure 5.1. At this stage, the concept of the web database design is much clearer for the reader as well as for a database administrator. Initially a company is selected from the drop-down list of company names. After the company name is selected, the names of products that the company manufactures appear in a drop-down list. Now the user selects a particular product, and once it is selected, they proceed to the next step. If the user does not choose an option then cannot proceed forward and remains at product selection. Once the product is selected, the information related to the product or device (i.e. its image, product description, and feedback by others) is revealed. The user can always go back and select another company name or product name to see other descriptions.

More detailed information about each step follows. Because tables are required for each step, relational model diagrams are drawn. These diagrams are a logical

representation of the relationship between data and the tables [66]. The relation schema of the databases to be used for this website is given in the table 5.1:

Table: 5.1. *List of Database Tables*

COMPANY (@CompanyID, CompanyName, ContactNo)
PRODUCT (@ProductID, ProductName, ProductDesc, ProductImage, @CompanyID → COMPANY)
DOCTOR (@DoctorID, DoctorName, DoctorPassword)
DOCTORFEEDBACK (@DFID, @DoctorID →DOCTOR, @ProductID → PRODUCT, Feedback)
USERFEEDBACK (@UserID, Username, UserFeedback, @ ProductID → PRODUCT, Status)
Where '@' represents primary key of table and → represents foreign key

Let's look at the individual table attributes and their description.

- **COMPANY:** Company is the main table which contains information about company name and contact details. Company Names are sorted into database according to company ID which is unique for each company that is why it is the primary key for company table.
- **PRODUCT:** Product table contains the information about product name, its descriptions, and image of products. Product table is linked with Company table with the help of company ID which is used as foreign key in product table.
- **DOCTOR:** The term doctor is used which belongs to both medical as well as scientific doctor which needs to be unique doctor ID and password to login into feedback page to enter the details or information about product. Therefore, doctor table consists of doctor ID, Name and password.
- **DOCTORFEEDBACK:** Doctor Feedback is the special table where advice about product is stored. This table contains doctor's feedback ID as primary key, feedback description, doctor ID and product ID as foreign key which is important to be located to separate which doctor writes about which product.
- **USERFEEDBACK:** User Feedback is the general purpose feedback column in the database as well as on the web because it helps others who want to know how the other patients feel about this product. This table consists of user ID always unique, username, feedback description, product ID about which product they are writing, and status which represents that the comment of user has been approved or not. This approval option is added in database because only relevant feedback is displayed on web.

The E-R Diagram for this scenario is shown in figure 5.8.

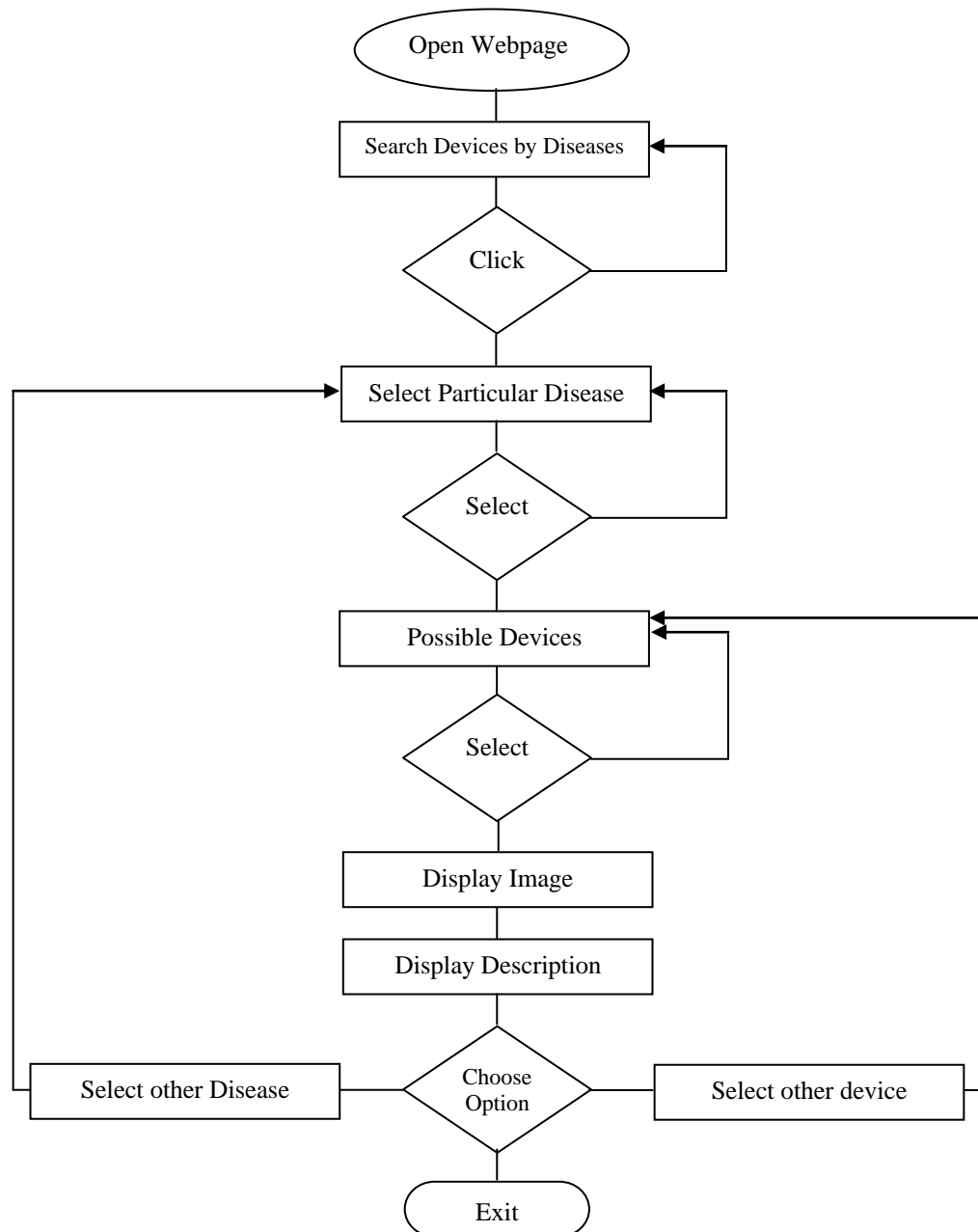


Figure 5.8. *E-R Diagram of Second Scenario*

CHAPTER 6

Results and Discussion

- Overview
- Reviews about Existing Tracking Devices
- Results of Tested Devices
- Results of Questionnaire
- Analysis about Tested Devices
- Outcomes of Website Implementation
- Importance of Web Application in Healthcare
- Research Work in MSc
- Future Development in Elderly Care

6.1. Overview

Different types of diseases may arise in everyday life for example a new strain of the flu, nerve or stomach tuberculosis, elderly problems, or sudden organ failures. These kinds of problems require immediate attention. So to face the new challenges of upcoming health problems, future planning in health care is important.

This thesis work is part of a beginning to prevent healthcare problems today and for future aging populations. This work started from the basic introduction about elderly care, moved on to a literary review about the elderly care devices, then the results of functional testing available about the devices, and finally concluding with the development of an online database system which is the theme of this thesis, for it provides awareness to the common person about available tracking devices important for the care of the elderly.

6.2. Reviews about Existing Tracking Devices

The literature review is the most important element in a research work. It is the part of the thesis where one reviews the critical points of the work [67]. The literature review is not for producing new ideas but for giving a clear idea to what is going on and what to do concerning research and development.

The review of available tracking devices reminds that research on these devices for elderly care started at least a decade ago. The common availability of GPS technology has boosted the mass research and production of GPS tracking devices. Previously

researchers focused on RFID technology, but now GPS receivers are widely used for different kinds of tracking devices and location finding purposes.

The literature review about tracking devices give perception into how different kinds of sciences are interlinked with each other to produce new products, and how these products have much more beneficial outcomes. Elderly care tracking devices are a merge of telecommunication and medical sciences. Most companies use GSM, GPRS and GPS technologies in the manufacturing of different types of these tracking devices. The devices are mostly developed in a manner to keep things as simple as possible due to that elderly people especially patients of dementia are usually unable to operate complex electronic devices. Tracking devices are user-friendly and consist of just two or three buttons that are pressed in cases of emergency, so that a caretaker or other responsible person is alerted.

6.3. Results of Tested Devices

6.3.1. Results of LDS Finder Device

The LDS Finder is one of these devices that are manufactured in Finland. In the performance analysis of the device, the main focus was on the efficiency and accuracy of the device. Table 6.1 gives the results that were observed in testing the device. The rating is given among one to five: 1 means poor performance, 2 for fair, 3 for average, 4 for good and 5 for excellent performance.

Table 6.1. *Observation and Testing Result of LDS Device*

Observation & Testing	Rating
Size of Device	3
Handling of Device (patient)	4
GPS Connectivity	2
Battery life	4
Accuracy on tracking via Web	3
Efficiency in sending Alert Message	5
User-Friendly	4
Overall Performance	3

The size of the device is satisfactory, but the handling is not exactly easy for elderly people. This is because it is sometimes difficult for them to remember to keep the device with them when they going out and that it must be turned on. This is why size matters in the manufacturing of devices for the elderly. The LDS Finder Device has no extra buttons other than the emergency button, and therefore it is easy to handle. Its GPS connectivity is a little slow: it takes about two to five minutes in connecting which may irritate the patient. The battery performance of the device is good and it works for at least for 3 days without needing charging. Web tracking is also straightforward, but

the map information is not too descriptive in accurately finding the exact location of the device. The efficiency of the device to send alert messages is excellent. Delay can be experienced depending on the mobile phone company service, but otherwise the device sends alert messages immediately. The device is overall user-friendly, and it does not take long to understand the functionality of this device.

6.3.2. Results of Teltonika HandHeld Device

The Teltonika HandHeld Device's performance was much better than the LDS Finder's because of the calling facility that makes its demand higher than other devices'. Table 6.2 explains the results received from the functional testing of the device. Rating values are the same as used in table 6.1.

Table 6.2. *Observation and Testing Result of Teltonika Device*

Observation & Testing	Rating
Size of Device	3
Handling of Device (patient)	3
GPS Connectivity	3
Battery life	4
Accuracy on tracking via Web	4
Calling or Receiving phone facility	5
Efficiency in sending Alert Message	5
User-Friendly	4
Overall Performance	4

The size of this device is the same as the LDS Finder Device, but its handling is a little more complex because there are five buttons to be pressed for different purposes. This may become difficult for elderly people because firstly they do not generally enjoy adapting to newer technology and secondly if the device is complex then they will avoid using it. Nonetheless, the GPS connectivity of the device is good but not as efficient as its alert messaging system. The call sending and receiving facility makes this device more attractive than the LDS device. The Teltonika device is also user-friendly, but it does take some time to learn all its features. Due to the calling feature and the faster GPS connectivity, this device tops the LDS Finder Device.

6.4. Results of Questionnaire

The questionnaire seen in Appendix 1 was conducted by EPTEK ry in Seinäjoki. The questionnaire asked users where they heard about the device, and all users replied that they learned about the device from EPTEK ry. The handling of the device was rated at easy, and replies said the device was used usually less than two hours at a time generally twice a week. With the help of the device, the surveyed said they are able to

live a bit more comfortably such as being able to walk outside alone without any helper. Almost every user replied that only a single device is enough for tracking purposes.

Although the LDS Finder is generally a simple device, still some users felt difficulty in handling it because they have never interacted with such technology before. Most of the users were satisfied by the battery performance which obviously has a high importance in these kinds of devices, and thus they were content with the low battery messages that the device output. Users replied as being interested in buying a new model of the device that is more efficient and whose webpage or mobile alerts respond even more swiftly.

An average user gave a rating of 3.3 out of 5 for the device, for most thought that the device needed to be more accurate and efficient especially in GPS connectivity because the device takes a long time in establishing a connection with a GPS satellite. Also, some called for webpage improvements because the webpage was not updating quickly and showed the current status with some delay. Nevertheless, with the help of this device, a nurse or caretaker's work is reduced, and this is first successful step towards making life easier for elderly patients and their caretakers. Some of suggestions given by the users were:

- This device must be foolproof.
- This device needs to be good enough for long-distance travelers.
- More accuracy is required and need location identifier inside the buildings as well.
- Device size needs to be smaller so that it is easy to carry.
- Clip of device needs to be better.

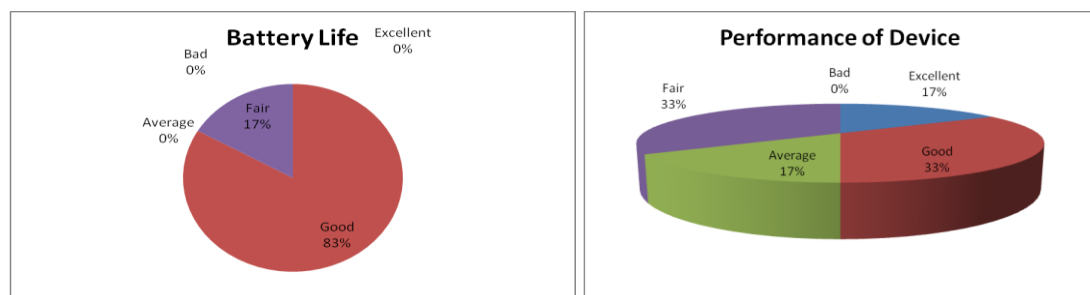


Figure 6.1(a). Survey Result about LDS Device Battery life. **6.1(b)** Performance

According to the survey results about the Teltonika HandHeld Tracker device, the users are much happier than users of the LDS Finder Device. They are satisfied with the device performance as well as not having many complaints about usability. This device can be used at least three times in a week and allows comfort in passing an independent life.

As expected, users did give their opinion about feeling a little difficulty in handling the device because of their unfamiliarity with electronic gadgets of the modern age. The

total rating of device was 3.5 out of 5 given by users who were willing to see this device commonly available everywhere. Not only were elderly people satisfied with this device, but also nurses and caretakers who can relax since the tracking device is being used. One of the most interesting suggestions given by users was that this device could be designed in a wrist watch shape because it is easier to wear something on one's hand instead of having something hanging off one's belt or being in their pocket.

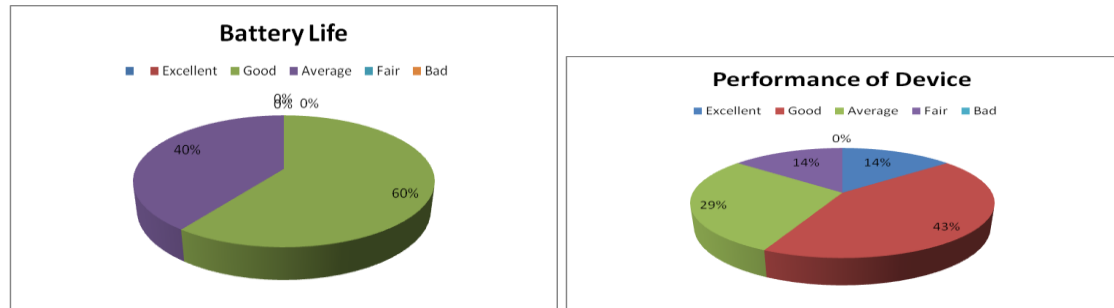


Figure 6.2(a). Survey Result about Teltonika Battery life. **6.2(b)** Performance

6.5. Analysis about Tested Devices

6.5.1. Analysis of LDS Finder Device

A one week performance analysis of the LDS Finder Device concludes that this is possibly the simplest tracking device for any type of tracking including auto vehicles, children, or animals. However, according to the manufacturing company, this device is particularly designed for people tracking. The best features noticed of the device are the size which allows it to accessibly be hooked on to a belt. It is fully waterproof, and shockproof if dropped onto a hard surface. The device is manufactured by using all standard technologies and protocols such as GSM, GPRS, GPS and IP-67.

This device is best used for dementia patients in situations where they wish to go for a walk or go to a nearby area. The patient must also remember what to do meaning they should know to press the red button on the device in cases of emergency. This is because there is no sensor technology built in the device that can detect the movement of the patient. For example, if the device is drops out of the patient's pocket, it will not send an alert or alarm, and if the patient is not feeling well and forgets to press the emergency button, then this device does not automatically sense any irregular movement or problem with the patient. Thus the user of this device must have enough sense to work with the device meaning it is a plausible solution for those who have low levels of dementia or Alzheimer's disease not those with excessive memory loss.

6.5.2. Analysis of Teltonika HandHeld Device

This device was only tested for a day and because of this the performance analysis of the LDS Finder Device was more clear-cut because it was tested for a longer period of time. The Teltonika HandHeld devices are manufactured in many countries of Europe

and worldwide, hence they are more renowned than the LDS device. The connectivity via GPS satellite is more efficient than the LDS device. The device also has five buttons for different functionalities compared to the one on the LDS device. Possibly the best feature that has been tested is the phone call utility to contact customer support to figure out the device's location; the call connects within ten to fifteen seconds. The customer support representative is able to check the position of the device on a map. The separated buttons on the device for call accept or call reject, emergency, and SMS may cause some confusion or difficulty for elderly people. Like the LDS device, this device is also recommended for those dementias' patients who have minor memory problems. This device is also waterproof, shockproof, and hooks up tightly with one's belt.

6.6. Outcomes of Website Implementation

The online database is an important part of this thesis work because it will be beneficial for new customers of elderly care devices. This is not a comprehensive website, but it has full information about available tracking devices for elderly people. Thus it has become a part of e-health care or a public health widespread website. This website can be used in hospitals, by health care providers, and in research work. Right now, few resources are available where a collection of similar devices is available.

Today, all information is available online, and healthcare services are widely available on the Internet through doctors, nurses, or other health care staff. In the future, this work can be further extended by utilizing other kinds of medical devices. This way the website is not limited to elderly care devices but provides information about all the latest medical devices. Therefore, this kind of website is in today's demand and will continue to be as such in the future when certain disease or disability related devices will be required.

6.7. Importance of Web Application in Healthcare

The database system is not only limited to purposes of business. It is also important and helpful to healthcare nowadays. All patient records are maintained electronically because it is the cheapest and the fastest accessible means. It also allows hospitals to maintain full histories of patients in one record. A medical record of one patient can be sent from one doctor to another or even from one country to another swiftly and securely within a few minutes. This is why database systems are being used so widely in healthcare centers.

This database website is created for a collection of elderly care devices manufactured by different companies. It is part of the category of medical informatics and telemedicine. The database systems related to patient medical information are important because traditional ways of searching through files is considered slow. By developing the online database website, the web application has enhancements to offer

in the biomedical field. For example, it is good to have a web database for painkiller tablets, a database for children's medicine, or a database in which a person can find the symptoms of their disease and get some suggestions or solutions related to their issue. This type of online databases should be designed to be accessed via a computer using the Internet as well as being accessible on a mobile phone via WAP services.

6.8. Research Work in MSc

Two research projects have been carried out during this MSc. The first one was a BME Project titled "The Modern Trend in the Treatment of Dental Care by Combining Telecommunication and Dentistry" which was submitted to the University in a comprehensive report work. Briefly, Teledentistry is a dental surgeon operating on a patient in another city or country with the help of other dentists to overcome the problem of availability of dental surgeons in remote areas [68]. This was a group project along with University Professor Kari Mäkelä and a company, EPTEK (www.eptek.fi). Most of the work is related to a literature review about teledentistry, and 40 research papers were studied in this regard. In that research work observations were made on the difficulties of using that technology and its limitations. After that there were some trial practical implementations of teledentistry in the Seinäjoki central hospital in Finland. The main purpose was to study the working, the practical limitations, and the expansion of the technology in the future.

The second work is this diploma thesis titled "Tracking devices for elderly care system by using GPS and RF tags".

6.9. Future Development in Elderly Care

6.9.1. Elderly Care Devices

Although research work has already started in medical devices for elderly care, there is still a need for improvements. Elderly care devices direly need to be improved in performance and accuracy. As seen in the questionnaire results, users want elderly care devices that are small enough to wear on the arm just like a wrist watch. These devices should not only have tracking capabilities but also be able to measure heart rate, blood pressure, and temperature of the body. Currently, blood pressure apparatuses, pulse monitors, heart rate monitors, and glucose meter are all separately available. Some elderly people lose track of all these devices, and they forget where they put which device. Ideally there should be just a single device that can perform all these basic health checkups allowing all people to suitably keep the device.

6.9.2. Home Care Devices

Telemedicine can be a highly interesting field in which to pursue a career or even carry out further research. It is a much more demanding field in today's world especially

since it is beneficial to the elderly and those in rural areas where good health facilities are not readily available. For example, there are sometimes problems with distances from health centers, expensive treatments, or slow procedures that create problems or slow down the management of elderly persons. At present, developed countries are also facing a problem with an increase in the number of aged people requiring many fulltime nurses or caretakers to look after them. Also, sometimes there are few specialist doctors and treatments can be expensive. This problem can be addressed by home care services which reduce the requirement medical staff by almost half. Only serious issues of the elderly require immediate medical attention. [70]

The aims of research are the analysis of available facilities for elderly care, the search for problems or challenges which limit the access of medical facilities to remote areas, and the proposal of a solution to this problem. Publish research articles (conference papers & journals) help other researchers and give an advanced direction to developments in the specified field as in the field of telecommunication for this work.

Although research has started in this field, there are still many ambiguities in home based health care system development which should be clarified by research. For example, currently not all available devices are efficient and good enough to be relied on. Secondly, there is no standardization for telemedicine technology compared to the telecommunication field where certain standards such as 2G, 2.5G, 3G and upcoming 4G technologies, broadband, and Wi-Fi which are constantly updated.

The latest telecommunication technology gives cheap, fast, and more reliable methods of communication compared to the technologies of the last decade. The motive of this research is to develop home care systems that are easy to implement, affordable, and continuously available basis. The aim of this research is to provide:

- Cheapest, fastest, home based health care services provided in the whole country especially elderly and remote areas
- Construction of standard prototypes and patents for home based health care which are used by manufacturing companies of medical devices
- Develop separate centralized database system of those patients who are treated by telemedicine technology, must be available to the authorized person 24/7
- Security standard must be defined. There must be privacy and confidentiality of patient records
- Establishing a telemedicine department in every central or city hospital and making it an integral part of the hospital management system. [70, 71, 72]

CHAPTER 7

Conclusions

- Conclusion of Thesis

7.1. Conclusion of Thesis

The main goal of this thesis work was to introduce expected difficulties related to elderly care. This thesis also provides a possible solution to overcome one of the main problems that comes with elderly age.

If proper research and development work is initiated in this field today, then it is possible to propose a better solution to this problem tomorrow. Nonetheless, tracking devices are among the best solutions for patients of dementia. An IP Nursing System is the one of the best alternative solutions compared to the traditional looking after of the patients. GPS navigation system is publically available for everyone and is widely used for tracking vehicles or other similar purposes. Therefore, it can and should be used for developing tracking devices for elderly care.

The involvement of telecommunication technologies (GPS, GSM, GPRS) and IT (software engineering and computer networks) in the medical field has put forth a the new field called telemedicine which is playing an important role in the manufacturing of small to large scale devices that provide plenty of benefits to the healthcare industry. Tracking devices for elderly care are one of the most important requirements for today's world in development of healthcare. At present, normal methods of elderly care are utilizing numerous resources as well as an excessive amount of peoples' time. That is clearly not an efficient way of caring for elderly patients in any situation. [73]

In this way tracking devices are important in many situations. Furthermore, these devices should also be adapted to warn the nurse or caretaker in other cases of emergency such as an elderly person falling from bed, going outside at an inappropriate time, or lost on the way to some place. These are basic problems that are observed commonly in daily life, and if, by accident, a caretaker is negligent then these can become highly perilous problems. Timely precautions do not only save time, but also the money of an elderly person. Most elderly people do not enjoy having any kind of new gadget with them because they do not like to adapt to new technologies in their lives. Therefore, tracking device should be developed in such a way that they do not bother the elderly and function automatically.

The performance analysis of the LDS Finder and the Teltonika HandHeld devices give new ideas to what sort of improvements are required in the quality of these tracking devices. Although both devices are working well, the GPS signals are weak and take some time in establishing a connection with the satellite. These signals are also weak inside buildings. The Teltonika device has reduced this problem by utilizing the calling feature, while the LDS device manufacturing still needs to improve in this area.

Currently, all kinds of information related to tracking devices are available on the Internet which is the fastest and up to date method of receiving this information all over the world. Therefore, an online database related of these tracking devices is helpful for users because it gets information about devices and feedback about each device all in one place which is helpful for buying these devices.

Conclusively, elderly people deserve be taken care of in the same way as children and homes. Efforts must be made in this regard by research and development to make their lives comfortable and independent.

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APPENDIX 1: SURVEY QUESTIONNAIRE

Please tick only **one** option:

1. From where do you heard about GTS-200 Tracking Device?
 - ☐ Internet (Search Engine)
 - ☐ Website (<http://www.lds.fi/>)
 - ☐ From friend
 - ☐ Recommended by Physician
 - ☐ Other source
 - ☐ If other source write here _____
2. Is this device easier to use?
 - ☐ Yes, it is very easy
 - ☐ Yes, it is okay
 - ☐ Not much easier
 - ☐ Little bit hard
 - ☐ Very hard in use
3. How long you use this device in a day?
 - ☐ More than 15 hours
 - ☐ 10 to 15 hours
 - ☐ 5 to 10 hours
 - ☐ 2 to 5 hours
 - ☐ Less than 2 hours
4. How long you use this device in a week?
 - ☐ 7 days
 - ☐ 5 to 6 days
 - ☐ 3 to 4 days
 - ☐ 1 to 2 days
 - ☐ Less than a day
5. Which is the most important point you noticed about this device?
 - ☐ It designed according to my requirement
 - ☐ It is very cheap and reliable technology
 - ☐ It change my life, feel much relax
 - ☐ My family members are happy
 - ☐ Nothing any important

6. Have you feel comfortable in your life by using this device?
 - ☐ Of course I am very much comfortable
 - ☐ Someway comfortable
 - ☐ I feel just okay
 - ☐ Not much
 - ☐ Not comfortable
7. How many tracking device you have other than this?
 - ☐ More than 10
 - ☐ 7 to 9 devices
 - ☐ 5 to 6 devices
 - ☐ 2 to 4 devices
 - ☐ Only this devices
8. What do you say about overall performance of this device?
 - ☐ Excellent
 - ☐ Very Good
 - ☐ Good
 - ☐ Fair
 - ☐ Bad
9. Have you feel problem in handling this device?
 - ☐ Very much difficult to use
 - ☐ Little bit difficult
 - ☐ Only first time feel problem
 - ☐ No any problem
10. Are you satisfied with battery power?
 - ☐ Excellent performance
 - ☐ Good performance
 - ☐ Average performance
 - ☐ Less than average
 - ☐ Very bad performance
11. Give us your rating of this device?
 - ☐ 100%
 - ☐ 75 -99%
 - ☐ 50-74%
 - ☐ 25 to 49%

- Below 25%

12. Do you like to recommend other this device?

- Definitely Yes
- If someone ask
- Never

13. In which area you want to see improvement more in this device?
(Select more than one option)

- More battery power
- More efficiency in GPS connectivity
- More effectiveness of device & its webpage
- Availability in market commonly
- No any improvement required

14. Do you like to buy newer version of this device in future?

- Definitely
- I think before buy
- No, I will not buy

15. Which option describes best for you?

- My independent life based on GTS-200
- It gives relaxation to nurse
- I do not like this device
- Other
- If other explains here: _____

16. Any Comments & Suggestion about GTS-200 tracking device:
